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Computer-Aided Design Package for Designers of Digital Optical Computers

Quarterly Progress Report for Grant #N00014-90-J-4018 for Period 5/1/92 - 7/31/92

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Summary

This report covers progress for the period 5/1/92 - 7/31/92 on a jointly sponsored ONR/AFOSR grant to Rutgers University which supports research into the architecture and design of digital optical computers. This reporting period begins three weeks before commencement, which is when Profs. Murdocca and Stone leave the project for the summer for a related SBIR effort supported by Rome Laboratory. PhD student Majidi, who was supported as a graduate assistant on this grant, took a full-time job at the end of the 91-92 academic year in the Image Processing Institute at the University of Medicine and Dentistry in New Jersey. PhD student Vipul Gupta is now jointly supported by NEC as well as by this grant. The change in support for Gupta was encouraged in order to ensure that he can finish out the 92-93 academic year, since the grant has a completion date of 4/30/93. Although commencement is in the middle of May, there must be enough support to maintain Gupta until the end of June in order for him to finish the academic year. The man-hours devoted to the effort for this quarter reflect the reduced support during the summer: three man-weeks for Stone, 0 man-weeks for Murdocca, three man-weeks for Majidi, and nine man-weeks for Gupta.

Progress for this reporting period includes technology transfer of the CAD tools to a Rome Laboratory sponsored SBIR effort and technology transfer of the CAD tools to the in-house Photonics Center optical computing program at Rome Laboratory. Stone continued his progress on micro/macro optics for optical interconnection, and has completed a paper summarizing his work that is being submitted to Applied Optics. Gupta has made progress on exploring a method for interconnecting parallel processors in which a high bandwidth optical interconnect slowly reconfigures, while a number of small electronic interconnects reconfigure more quickly. Progress in these areas is detailed below.

Technology Transfer of CAD Tools for Digital Optical Circuits

The CAD tool development has moved into a transition phase in which practical circuits are being designed for other institutions. Rome Laboratory has picked up the cost of hiring two Rutgers undergraduate students to modify the tools to address the folding problem, in which rectangular shaped circuits are folded to match the square shapes of optical logic arrays. The students have been supported for the 1992 summer months through the SBIR program. In a separate effort, the

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CAD tools are being used by Murdocca to design and simulate a small decoder circuit for an S-SEED testbed processor that is under development in the in-house optical computing program at the Photonics Center at Rome Laboratory. Murdocca is attempting to modify the RL decoder design so that half of the masks can be removed, which will eliminate the need for two imaging stages in the RL setup.

Birefringent Interconnects and Optical Array Generation
Stone has completed a paper describing the technique of array generation using cascaded slabs of birefringent materials. Microlasers can serve as efficient optical array sources, and the use of cascaded birefringent slabs can be used to increase source redundancy and to modify the coherence properties of the arrays. These capabilities were emphasized in the paper, which is being submitted to Applied Optics.

Optical Interconnects
Stone continued his progress on studying properties of hybrid micro-optics/macro-optics for optical interconnects. This work builds on the conclusions of our previous studies that characterized 1) the limits of scaling conventional macro-optical interconnect systems, and 2) the propagation distance limits in the micro-optical interconnect extreme imposed by diffractive crosstalk. The requirements of small spot sizes on devices and large field angles (which are necessary to accommodate large device arrays) usually give rise to very complicated optical designs for the resulting highly constrained lenses. A concept of "segmented field compensation" is being studied as one way in which this lens complexity may be reduced. In this approach the "macro" lens is simplified and the resulting aberrations, which vary with field angle, are corrected by arrays of compensating diffractive microlenses which are arrayed across the device field. Other general approaches to hybrid optical systems that can reduce lens complexity and enhance scalability to large device arrays are being investigated.

Investigation into Reconfigurable Interconnects
Gupta continued his work on reconfigurable interconnects in a collaboration with NEC. For the summer months, 80% of Gupta's support is from NEC and 20% is from the ONR/AFOSR grant. Gupta has focused on a model of reconfiguration that makes use of a large but slowly changing reconfigurable optical interconnect that connects a number of small but fast electronic reconfigurable interconnects. Many parallel applications exhibit *switching locality* in which each process tends to communicate directly with only a small set of other processes for a given interval of time. An Interconnection Cached Network exploits switching locality to gain high performance. In such a network the set of communicating processes is partitioned into small clusters. Processes in the same cluster communicate over small, fast electronic switching networks. A slowly reconfiguring high-bandwidth optical network interconnects processes in different clusters. Efficient embeddings of communication structures can be obtained for such a network to ensure that the large, slowly reconfiguring network need not switch very often.

In order to embed communication patterns efficiently in this architecture, we need to know if the communication graph has a bounded l-contraction. The bounded l-contraction of an undirected, connected, bounded-degree graph G is defined to be a partitioning of its sets of nodes into partitions of size at most l, such that the size of each partition is at least as large as the number of its neighboring partitions.

The problem of identifying whether a graph has a bounded *l*-contraction for a given integer *l* is known to be NP-complete for $l > 2$. Gupta and Eugen Schenfeld (NEC) have developed a heuristic algorithm based on simulated annealing for this problem and have tested it on classical topologies such as trees, grids, hypercubes, and cube connected cycles.

Equipment

The Thomas & Betts Corporation in Bridgewater, New Jersey, donated a 4' × 6' Newport optical table to our group. The donation included flotation mounts and a film cabinet. The table and cabinet will be helpful for experiments planned by Stone using the new DMP-128 photopolymer that we will obtain soon from Poloroid.

Publications and Presentations

The following publication was submitted for publication during this reporting period. The ONR and AFOSR sponsoring agencies are acknowledged in the paper.

Publication

T. Stone and J. Battiato, "Optical Array Generation and Interconnection Using Birefringent Slabs," submitted to *Applied Optics*.

Plans for The Next Reporting Period

During the next quarter, Stone's optical interconnect studies will continue. An emphasis will be placed on experimental study of the interconnect concepts. Murdocca will focus on architectural tradeoffs between regular and irregular optical interconnects. Gupta will continue his investigation into switching locality in the context of reconfigurable optical interconnects.

Miles Murdocca